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Citation: In ”New and Emerging Technologies in the Food Industry” (2003) Publications by AlChE Presentations 108b 1-6

Number: 7366

TRIALS AND PITFALLS AND THEN SUCCESS IN DEVELOPMENT OF THE VSV SURFACE INTERVENTION PROCESS

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Key Words: food safety, meat, poultry, hot dogs, cantaloupe, fruit, vegetable

Prepared for presentations at the 2003 Annual Meeting, San Francisco, CA, Nov 16-21
CoFE 2003 - Eighth Topical Conference on Food Engineering

T5014 New and emerging technologies in the food industry
Unpublished

ABSTRACT

We developed a process, the Vacuum/Steam/Vacuum (VSV) process, which kills bacteria in the surface of solid foods. It is a rapid process and should be able to keep up with typical line speed in a process plant. Typical treatment times are 1 – 2 s. The primary goal was to develop a process to kill bacteria on chicken with no thermal damage. The process involves removing the air and water film barriers on the surface so saturated steam can make intimate contact with the bacteria. Vacuum removes these films. Steam then kills the bacteria. A final vacuum step evaporatively cools the product surface, hence the process name - VSV. Because the saturated steam condenses on contact depositing a new film of water, cycling between vacuum and steam improves the process.

The ideal process would kill up to 5 log bacteria on chicken. However, chicken presented many difficulties. It is wet from upstream processing. It has numerous "hiding places" such as under the wings, under the legs, in the skin folds especially at the top and bottom. The worst hiding place is in the visceral cavity. Chicken carcasses are also very susceptible to both thermal and mechanical damage. The skin and meat readily reveal thermal damage and the carcasses rip easily. In spite of these obstacles, we developed a process that kills 1 – 1.5 log of bacteria with little or no thermal damage and no mechanical damage. The research was a technical success but industry is not knocking down the doors because of the relatively low bacteria kill and high initial capital cost.

However, along the way, we developed the VSV process for various other foods, most notably hot dogs. We were able to achieve up to 5 log kill of surrogate bacteria on hot dogs. As a result of this spin-off, we entered into a Cooperative Research and Development Agreement with industry to commercialize the process. Commercialization is imminent.

KEY WORDS

food safety, meat, poultry, hot dogs, cantaloupe, fruit, vegetable

INTRODUCTION

Post-harvest thermal processes such as blanching and cooking can destroy harmful bacteria on foods. However, raw foods harbor bacteria, sometimes pathogenic bacteria. The many recalls attest to the occurrence of bacteria slipping through the food system to product distribution.

Raw foods harbor bacteria in and on the surface. Steam can kill bacteria but will thermally damage the food surface. If steam is applied very rapidly for a short time to a food surface and immediately cooled there is virtually no thermal damage (Morgan, et al., 1996a). A thin layer of air and water on the surface interferes with the rapid treatment. Morgan, et al. (1996b) developed a concept in which these layers of air and water are first removed by vacuum. Then saturated steam is rapidly applied and reaches into the pores that harbor bacteria. A second application of vacuum rapidly evaporatively cools the surface stopping any thermal damage.

Goldberg (Morgan, et al., 1996a) developed a machine capable of evacuating the surface, applying saturated steam, and evacuating the surface again in less than 1 s. The process is called the Vacuum/Steam/Vacuum (VSV) surface intervention process. The short treatment time is sufficient to kill bacteria yet short enough to prevent thermal damage to the chicken surface.

Kozempel, et al. (2000a) found that cycling the treatment enhanced the bacteria kill. This is understandable because the condensing steam immediately forms a resistance layer to further treatment. By cycling between vacuum and steam, the condensed steam is removed and fresh steam contacts the surface.

RESULTS AND DISCUSSION

Initial experiments used chicken parts bought at local supermarkets. Breasts and drumsticks were inoculated on selected exposed area with *Listeria innocua.* Bacteria reduction on the selected areas was 1.8 log on breasts and 2.4 log on drumsticks. When the VSV process was tested on whole broilers, there was no bacteria kill (Kozempel, et al., 2000b). The process failed with whole carcasses because the VSV process did not treat the cavity of the carcass.

The VSV process chamber was retrofitted to include a mandrel to hold the carcass (Kozempel, et al., 2001). This mandrel specifically treated the internal cavity. Unfortunately, this retrofit prototype VSV processor was not satisfactory as a predictor of a commercial unit. The mandrel was locked into moving with the main valve so it rotated horizontally during processing. The chicken carcasses tended to slide partially off the mandrel. The retrofitted mandrel proved that the concept of a mandrel would work but the actual bacteria kill was only about 0.7 – 0.8 log.

A new VSV processor was needed in which the mandrel was operated independently of the main valve. It was also desirable to design and build a mobile unit that could be used in the field to test at actual poultry processing plants. Therefore, a new mobile VSV surface intervention processor was designed and fabricated with a properly designed mandrel.

A prototype field unit containing one chamber and a mandrel in one rotor was designed and constructed. The product treatment chamber is spherical for a broiler carcass. The chicken carcass is suspended on a specially design mandrel to treat the visceral cavity.

The carcasses were inoculated by immersion in a suspension of 10^6 cfu/ml *Listeria innocua* or *E. coli* K-12 for 10 min. The carcasses were allowed to drain in ambient conditions for 30 min before experimentation. Chicken carcasses used for the field studies were not inoculated.

Pilot Plant - I

Initial attempts using 1 cycle to process broilers resulted in extensive mechanical damage to the carcasses. The carcasses were ripped up the side and many actually fell off the mandrel for lack of sufficient integrity. These initial mandrels were nothing more than a perforated pipe of various lengths and diameters.

The side of the carcass is quite thin and easily ripped. The mandrels were changed to incorporate support for the cavity. Screening was added to support the carcass within the visceral cavity from the neck down. This virtually eliminated the mechanical damage in the pilot plant. The mean kill for inoculated *L. innocua* was 1.13 log cfu/ml. The mean kill for inoculated *E. coli K12* was 1.36 log cfu/ml. Incidence of tearing was 10%, still unacceptable but much improved.

Field Tests

Although the mechanical damage problem was only partially solved, the field tests were conducted as scheduled to determine microbiological kill. The VSV unit was installed on a flat bed truck and driven to close proximity of a chicken processor. Freshly slaughtered and processed chickens were pulled before the chill tank and immediately transported unchilled.

2^3 factorial experimental designs were used to evaluate the field tests. The best conditions were 3 cycles and 138C saturated steam. At these condition the field VSV surface intervention process killed 1.3 log of *E. coli* and 1.2 log of *Campylobcater* on freshly processed whole chicken carcasses. The field studies duplicated or exceeded the microbiological kill found in the pilot plant

The carcasses encountered in the field test were much smaller breasted than the ones used in the pilot plant studies. The mechanical damage was greater than expected because of the difference in the carcass dimensions. With large breasted carcasses, the mandrel worked fine most of the time. However, with these small breasted chickens the carcasses sat lower in the chamber. When the main valve closed, one of the legs invariable got stuck in the valve. The end of one leg on almost every carcass was broken. This caused two problems, a vacuum and steam leak and mechanical damage. When the leg got caught, it pulled away from the side and ripped the side open. We had similar experiences in the pilot plant with earlier mandrels.

Pilot Plant - II

The objectives of the follow-up pilot plant studies were to eliminate the mechanical damage experienced in the field while maintaining the microbiological kill. The leg breakage was simple to eliminate. The previous prototype processor had a screen in the bottom to hold the chicken. Once the mandrel was used to support the carcass, it was considered superfluous. However, it kept the legs from extending beyond the chamber. A perforated plate was added to the bottom of the mandrel to support the legs and leg breakage was no longer a problem. The mechanical modifications had no statistically significant effect in the microbiological reduction. Bacteria reduction was still 1.0 – 1.5 log.

SPIN-OFF

We studied the application of the VSV process to other products. Up to 5 log reduction of inoculated *L. innocua* were achieved with hot dogs. This application is currently under commercial development through a Cooperative Research and Development Agreement (CRADA). We have also successfully applied the VSV process to whole eviscerated catfish with bacteria reduction of 2.0 log.

Another potentially large application for the process is with fruits and vegetables. Table 1 lists the various products investigated. The extent of bacteria reduction is obviously dependent on the physical structure of the surface. None of the fruits and vegetables listed showed any sign of thermal damage.

TABLE 1

Application of the VSV surface intervention process to fruits and vegetables

Commodity	Bacteria	Control Log cfu/ml	Treated Log cfu/ml	Kill Log cfu/ml
Cantaloupes	*APC*	5.6	2.2	3.4
Carrots	*APC*	5.6	--	>5.0
Grapefruits	*APC*	3.6	--	3.6
Papayas	*L. innocua*	5.2	1.6	3.6
Mangoes	*L. innocua*	5.4	1.4	4.0
Avocados	*L. innocua*	4.1	1.0	3.1
Kiwis	*L. innocua*	6.4	1.6	4.7
Carrots	APC	5.7	1.6	4.2
Cucumbers	APC	5.4	1.6	3.8
Peaches	*L. innocua*	5.0	1.4	3.6

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CURRICULUM VITAE

As a Chemical Engineer/Lead Scientist has spent over 35 years in research developing processes, for example, syntheses of an acylation chemical intermediate, of a pharmaceutical, fractionation of animal fat for a cocoa butter substitute, isolation of biologically active plant components, modeling and simulation of food processing, and development of novel, thermally benign pasteurization processes. Has been extensively involved in technology transfer for simulation and modeling technology and food processing. Four of the research projects culminated in commercialization, i.e. the isopropenyl stearate process, the ERRC Food Process Simulation software, Neem seed biological insecticide, and spice sterilization. A fifth, VSV surface pasteurization of hot dogs, is expected be commercialized soon. Have over 70 publications and 7 patents.

EDUCATION

Villanova University; major, Chemical Engineering; B ChE. 1964.
Villanova University; major, Chemical Engineering, M ChE. 1973

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